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The Yellow-Red Spectrum of Nova Aquilae No. 3

The yellow-red region of the spectrum of novae has not been studied as extensively as the green-blue-violet region. This region has in recent years become available by the use of stained plates which make its study as feasible as that of the other part of the spectrum. Its features have been discovered and described only partially and principally in the case of *Nova Geminorium* No. 2, 1912[1], the latest nova preceding the present one, sufficiently bright to be studied.

A long series of plates of *Nova Aquilae* on fifty-one dates between June 14 and October 25, 1918, taken with one prism, has been secured at Mt. Hamilton. These plates are Seed's 27 stained with Wallace's pinacyanol-pinaverdol-homocol formula and show well the region 4800 A to 6700 A, taking in the strong hydrogen Hβ and Hα. Owing to the various intensities of different features of nova spectra, these plates certainly cannot have recorded all the features that may have existed in the spectrum, but they contain a great deal of detail. A study of all the lines and bands, their positions and shifts, their structures, characteristics and developments, and their relations and associated changes, which make up a gamut of metamorphoses whose origin and meaning are yet to be learned, would require much time and printing space. The attempt here will be only to give a list of the observed bands and a few of their conspicuous characteristics. Because of many overlappings there is difficulty at places in deciding on the delimitations of the individual bands.

A descriptive list is given farther on containing a column of the spectral features measured, a column of their positions in wave-length or angstrom units, and a column of interpretations which contains brackets designating spectral bands and the wave-length of their centers followed by numbers referring to the paragraphs of description and data below. As practically all the measures, which are for the present only approximate, were made on two plates, one of June 19 and one of August 3, selected as typical of the aspect and content of the earlier and the later spectrum, the brackets have been separated into two columns in order to give some idea of the groupings of the bands at the two epochs.

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[1]Adams and Kohlschütter, *Contributions from the Mt. Wilson Solar Observatory* No. 62, III, 243, 1912; also *Ap. Jour.*, **36**, 293, 1912.

The two intense broad hydrogen bands, $H\beta$ and $H\alpha$, with their tube-comparison lines on either side, have thruout the observations stood like sign-boards along a roadway, conspicuously fixed at either end of the extent of spectrum here presented, and likewise the helium band D_3 which entered the field midway about June 20. When D_3 came in the sodium band composed of D_1 and D_2 soon vanished with its pairs of narrow absorption lines on its violetward edge and across its middle. Helium bands 4922 A and 5015 A were strong in June and gradually diminished. The nebular bands 4959 A and 5007 A, overlapping one another and the two helium bands just mentioned, developed soon after June 20 and became continually more conspicuous. The well known nebular band 5754 A has been a most conspicuous object with its central bright core intense and sharp-edged thruout the observations. Two bands, also well known, 5678 A and 6300 A, have been strong most of the time. Helium 6678 A has appeared frequently but always faintly.

Widths of bands seem to remain practically constant, their values ranging from 30 to 80 angstroms, while those of the central cores described below range from 14 to 20 A. These widths in many cases seem greater than those in other novae spectra, and this has caused some of the overlapping mentioned above.

All the brighter bands have shown central cores, some bright, that is, brighter than their respective bands, and some as absorption. The bright and absorption phases have interchanged at times in some of the bands, most conspicuously those of hydrogen, helium, and nebulium, also of 5678 A. Band cores 5678 A, He 5875 A, and 6300 A have shown changes in connection with other changes in the spectrum, as described below. The intense bright core of 5754 A has remained bright and has never been replaced by absorption during the whole interval of observation, but has shown slight variations of intensity. Its constant super-brightness and sharp definition have been remarkable.

The interpretations attempted in the subjoined columns and descriptive paragraphs are aided somewhat by the record of *Nova Geminorum*, but are nevertheless inconclusive in several cases. It may be that some of them must be taken as alternatives, unless they have different times of development or undergo complications, points which probably require more observational data and study. Altho the region 5026 A to 5068 A is definitely bright at times, its

identification with helium 5047 A may be uncertain because of the overlapping bands. The relation of the bright core at 5061 A to adjacent features is quite undeterminable and the grouping 5038 A to 5084 A is only an alternative appearance. The band 5060 A to 5084 A is apparently an isolated object on some plates late in June. Band 5665 A, with limits 5634 A to 5695 A may be considered doubtful, but band 5678 A when strong, is definitely an independent band. The object 5634 A to 5708 A sometimes appears like the complex hydrogen bands when they present the double bright portions with wide absorption across the middle and less intense wings on either side. Bright band and absorption features in the regions 5786 A to 5864 A and 6419 A to 6520 A are certainly visible but very variable and any definite delimitations hardly possible. The centers 5824 A, 6457 A and 6475 A are only suggestive effects. Similar suggestions may be given for the region 5912 A to 6021 A. Object 5971 A to 6038 A is definitely the band 6004 A and the same may be quite safely decided for band 5944 A with limits 5912 A to 5976 A. But at times it is hardly possible to determine the relation of the bright core at 5960 A to adjacent features and the apparent band 5983 A between 5945 A and 6021 A may be only a transition effect.

One more group of bands difficult to dissect, lying between 6263 A and 6408 A, which have been designated definitely as two, 6304 A and 6370 A, in the case of *Nova Geminorum No. 2*, but which touch or overlap in the present nova spectrum, may still be defined as the same two with the same centers. But on only one or two plates did band 6370 A give the appearance of having a central core or of being a complete and independent band. When this group is strong it appears as one broad complex band, somewhat like the hydrogen as just referred to in connection with 5678 A, but having, instead of broad absorption across its middle, a fairly narrow sharp absorption line centered at 6331 A. The apparent middle of the portion 6263 A to 6327 A precedes the center of its frequently well-defined bright core, thus suggesting that it is cut off or overlapped by the absorption line. The definitive interpretations of the complicated regions will require thoro study.

Certain groups of bands seem to show similarities and simultaneous changes. One set, composed of bands 5168 A, 5314 A, 5577 A and 6004 A, are present in June and July with fairly sharp edges

or limits. At times the individual bands are of uniform intensity and at others the first three, at least, show faintly a brightened core 17 angstroms wide. They gradually become faint and diffuse and practically vanish when a certain other set appears at its strongest. This latter set, composed of bands 5175 A, 5290 A, 5410 A and 5536 A, seems to have a recurrent nature, appearing nearly always faint, on June 26-28, July 21-23, August 3-5, August 23, and September 1. The array was conspicuous on August 3 to 5, when discovered, and gives the appearance of a group of grooves or troughs with fuzzy edges with an average of twenty-two angstroms of absorption across the middle. When these bands flash up, the cores of bands Hβ, 5678 A, and He 5875 A change from bright to absorption, the redward portions of Hβ, N_1, and He 5875 A increase in brightness, and the bright core of band 6300 A sharpens up. These concurrent changes may be associated phenomena but need further study.

The sets of bands also exhibit the relations that their widths increase with increasing wave-length and that for the second set the second differences of their positions or wave-lengths seem to approach a constant value. These relations are shown by the following table:

TABLE I

First Set				Second Set			
Wave length	1st diff.	2nd diff.	Width	Wave length	1st diff.	2nd diff.	Width
5168 A			56 A	5175 A			57 A
	146				115		
5314		117	59	5290		5	62
	263				120		
5577		164	64	5410		6	62
	427				126		
6004			67	5536			65

Whether these bands possess series relations would be of interest to discover, but this will not be undertaken here. Only the first set seems to have been observed in *Nova Geminorum No. 2*, 1912, but the second set was observed by means of orthochromatic plates in the spectrum of *Nova Persei*, 1901[2], where they appeared as very diffuse simple bright bands. The character of these bands, as shown in *Nova Aquilae No. 3*, 1918, is probably new to our knowledge of nova spectra.

[2]Campbell and Wright, *L. O. Bull.*, **1**, 46, 1901.

TABLE II

MEASURES AND BANDS

Feature	Wave length	Interpretation			
		Bands		Centers	Note
		June 19	Aug. 3		
Beginning bright	5026A				
Beginning bright	5038			5047A	1
Bright core center	5061				2
Edge bright core	5068			5061	3
Absorption line	5070			5070	4
Ending bright	5084				
Sharp beginning bright	5140				
Beginning bright	5146			5168	5
Sharp ending bright	5196			5175	6
Ending bright	5203				
Beginning bright	5259				
Sharp beginning bright	5285			5290	6
Ending bright	5321			5314	5
Sharp ending bright	5344				
Beginning bright	5379			5410	6
Ending bright	5441				
Beginning bright	5503				
Sharp beginning bright	5545			5536	6
Ending bright	5568			5577	7
Ending bright	5609				
Beginning bright	5634				
Beginning bright	5647			5665	8
Bright, absorption, core center	5676, 7			5671	9
Ending bright	5695			5678	10
Ending bright	5708				

TABLE II—*Continued*

MEASURES AND BANDS

Feature	Wave length	Interpretation Bands June 19	Bands Aug. 3	Centers	Note
Sharp beginning bright	5721A				
Bright core center	5754			5754A	11
Sharp ending bright	5786				
Absorption line	5824			5825	12
Beginning bright	5864				
Faint absorption line	5912			5892	13
Ending bright	5921				
Beginning bright	5945			5944	14
Beginning bright	5971			5960	15
				5983	16
Ending bright	5976				
				6004	17
Ending bright	6021				
Ending bright	6038				
Beginning bright	6129				
				6158	18
Ending bright	6187				
Beginning bright	6263				
Bright core center	6300			6300	19
Ending bright	6327			6335	20
				6331	21
Beginning bright	6335				
				6371	22
Ending bright	6408				
Beginning bright	6419				
Beginning bright	6441				
				6457	23
Bright core	6457				
				6475	24, 25
Ending bright	6494				
Ending bright	6615				
Beginning bright	6639				
				6676	26
Ending bright	6712				

NOTES

1. Possibly helium band with wide absorption across middle, overlapped by strong N_1 (ending at 5035A), and with wing toward the red. Appears in July and August.

2. Bright core band 14A wide.

3. Possibly band with bright core center, apparent on some plates in July.

4. Apparent band with absorption center, on some plates late in June.

5. Sharp-edged band with sharp absorption line on violetward side and bright core 17A wide, present during June and July.

6. Fuzzy-edged band with about 22 angstroms of absorption across middle, appearing at intervals during July and August, strongest on August 3-5.

7. A generally ill-defined band with bright core 17A wide, present during June, faint later.

8. Possibly a separate band with absorption core. It appears isolated on June 15, before bands 5678A and 5754A had developed, with absorption center at 5662A, but with the redward portion (center at 5677A) slightly brighter than the other.

9. Complex band most frequently ill-defined, with bright or absorption core, the portion to the violet appearing as a wing. Features sharpened on June 26-28, and at intervals afterward.

10. Band strong after June 25, sharpening at intervals with core of absorption replacing bright core. Core ill-defined, 20A wide, bright when band is not sharp.

11. Very strong well known nova band with sharp edges and stronger bright core, 15A wide, edges always sharp.

12. At times appears as a band with center at 5824A.

13. Sodium bands D_1 and D_2, strong up to June 21, then replaced by strong helium D_3 (5843A to 5907A).

14. Band with slight, unsymmetrical absorption, possibly overlapped by helium D_3, apparent in July and August.

15. Bright core, with absorption each side, appearing differently related at different times.

16. Apparent, ill-defined band following the disappearance of 6004A.

17. Faint early band with fairly defined limits and with absorption across middle at times.

18. Diffuse band, generally faint, with absorption across middle at times.

19. Strong band with middle point at 6295A, edges sharpening at intervals, particularly on August 3. Core always bright, 18A wide, not always sharp-edged, and not (on August 3) central with the apparent limits of the band.

20. These features, frequently diffuse, often appear as one broad band with narrow absorption across middle and wing sections on either side.

21. Apparently strong absorption, possibly space between two bands.

22. Probably a separate band, altho apparently without a central core, the left half being brighter than the right half.

23. Possibly center of ill-defined band (6419A to 6494A) with slightly bright core, apparent on early plates.

24. Later this portion appears as bright core with center at 6470A.

25. This interval appears as a background for Hα (6520A to 6602A), but is probably composed of a band whose center precedes Hα and of a wing to Hα on its redward side. At times absorption appears across the first part preceding the edge of Hα band.

26. Helium band with absorption across middle, always faint.

G. F. PADDOCK.

November, 1918.

MOVEMENTS OF FOUR UNKNOWN LINES IN THE SPECTRUM OF NOVA AQUILAE, 1918.

Two pairs of unidentified absorption lines which appeared intermittently in the spectrum of *Nova Aquilae* have shown conspicuous changes of position or wave-length. In each pair the two lines have appeared and disappeared together, maintained equal intensities and practically constant distances apart, moved equal amounts at the same times, and in all respects have behaved like duplicates. There seems to be, however, no definite relation of the times of appearance or disappearance of the pairs to each other; but the pair whose greatest observed wave-lengths were 4061A and 4068A always appeared and disappeared simultaneously with the sharp and narrow absorption lines of hydrogen, while the pair whose greatest observed wave-lengths were 4560A and 4576A were in general present at the